MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2018/2019

EOP3046 – OPTICAL WAVEGUIDE AND DEVICES

(OPE)

23rd OCTOBER 2018
9:00 a.m. – 11:00 a.m.
(2 Hours)

INSTRUCTION TO STUDENT

1. This Question paper consists of **6** pages with **4** Questions only.
2. Attempt **ALL FOUR** questions. The questions do not carry the same marks distribution. The marks distribution for each question is given at the end of every question.
3. Please print all your answers in the Answer Booklet provided.

Question 1

(a) A ray of light in air, makes an angle of incidence of 45° at the center of the top surface of a transparent cube of refractive index 1.414 as shown in Figure Q1(a). Trace the ray through the cube.

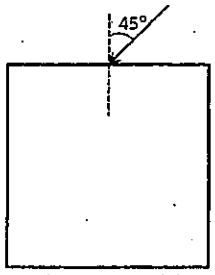

Figure Q1(a)

[6 marks]

(b) Explain total internal reflection with proper diagrams. Show cases of incident angles smaller than, equal to and greater than the critical angle.

[6 marks]

(c) A light wave is travelling in a glass of refractive index 1.50. If the electric field amplitude of the wave is known to be 100 V/m, find:

i. The amplitude of the magnetic field.

[2 marks]

ii. The average magnitude of the Poynting vector.

[4 marks]

(d) Consider a graded-index fibre with a parabolic refractive index profile that has maximum refractive index value of 1.5 and index difference of 1%. Estimate the maximum possible core diameter which allows single-mode operation at a wavelength of 1.3 μm. Given that

$$V = 2.405\left[1+\frac{2}{\alpha}\right]^{1/2}$$

where V is the normalized frequency and α is refractive index profile.

[7 marks]

Continued...

Question 2

(a) State all sources of absorption in optical waveguides.

[6 marks]

(b) Identify the mode number for the mode profiles in Figure Q2-(b).

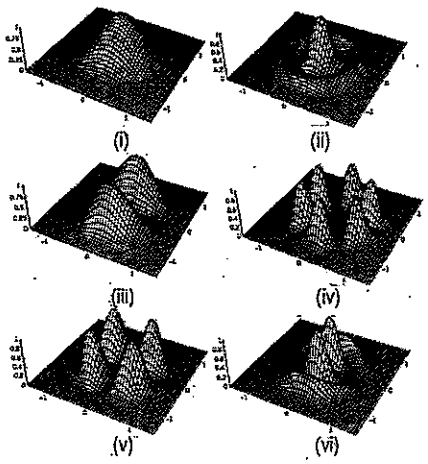

Figure Q2-(b)

[6 marks]

(c) With the help of a sketch, describe how graded index fibre can reduce intermodal dispersion.

[5 marks]

Continued...

(d) Describe the origin of *Stimulated Raman Scattering* (SRS). In addition, using a diagram, describe how SRS can be detrimental to optical signal transmission through optical fibre in:

i. Time domain – consider when we have two laser lights that are modulated with a square pulse train with slight time delay as in Figure Q2-(d-i).

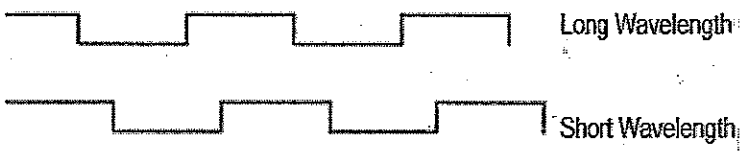

Figure Q2-(d-i)

ii. Frequency domain – consider when we have five *Wavelength Division Multiplexing* (WDM) channels as in Figure Q2-(d-ii).

Figure Q2-(d-ii)

[8 marks]

Continued...

Question 3

(a) (i) Design a basic planar waveguide with an incorporated diffraction Bragg grating. Illustrate the design schematic with the ray propagation inside the structure and describe the wavelength filtering principle.

[5 marks]

(ii) Starting with the general equation for a diffraction grating, derive the Bragg condition for the first order diffraction ($m=1$), i.e. the reflected wavelength λ_B as a function of the grating period D and effective refractive index n_{eff} for the planar waveguide grating.

[5 marks]

(b) (i) A 2×2 directional fibre coupler is composed of tapered and interaction (i.e. coupling) fibre sections. Explain the influence of these sections on V-number for the operation of this device.

[5 marks]

(ii) Explain the term *splitting ratio* and *crosstalk*, respectively, of a 2×2 directional fibre coupler, and formulate their corresponding mathematical expression.

[5 marks]

(ii) A lossy 2×2 symmetric biconical tapered waveguide coupler has an input optical power level of P_0 = 200 μW. The optical loss coefficient, α in the waveguide is 0.02 dB/mm and the coupling coefficient, κ is 0.5 mm^{-1}. Calculate the output of the driven waveguide with a length of 3 mm.

[5 marks]

Continued...

Question 4

(a) (i) Using a relevant schematic diagram, describe the fibre-optic fabrication technique based on plasma-activated chemical vapour deposition (PCVD).
[6 marks]

(ii) Why is it possible to fabricate graded-index fibres using the PCVD process?
[3 marks]

(iii) What is the advantage of using the plasma-assisted mechanism?
[2 marks]

(b) (i) State two parameters that will determine the deposition rate of thin film using the evaporation technique.
[3 marks]

(ii) Suggest one approach to obtain good uniformity of the deposited alloy film in the evaporation process.
[4 marks]

(c) (i) Define concisely the sputtering process.
[3 marks]

(ii) Discuss how the sputtering technique makes the deposited film on the wafer surface has good adhesion.
[4 marks]

Continued...

Appendix A

Physical Constants and Units

Constant	Symbol	Value (mks units)
Speed of light in vacuum	c	3×10^{8} m/s
Electron charge	q	1.602×10^{-19} C
Boltzmann's constant	k_B	1.38×10^{-23} J/K
Permittivity of free space	ε_0	8.8542×10^{-12} F/m
Permeability of free space	μ_0	$4\pi \times 10^{-7}$ N/A^2
Electron volt	eV	1 eV = 1.602×10^{-19} J
Planck's constant	h	6.626×10^{-34} J·s

End of the paper.